Atmospheric Modeling Support For CREAMS II: Simulations of Mesoscale Atmospheric Circulation and Forcing in the Japan/East Sea

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LONG-TERM GOAL

The PI's long-range goal is to understand the physical processes of the air-sea interaction and coupling of the ocean and the atmosphere on the regional scale and to predict the variability of the coupled ocean-atmosphere system.

OBJECTIVES

The main objectives of this study are (1) to better understand the influence of the wintertime Siberian cold-air outbreaks and their interaction with the complex coastal terrain on the surface forcing in the JES region and (2) to investigate the effects of the surface winds and air-sea fluxes on the ocean circulations and surface waves in JES.

APPROACH

We use the Penn State University/National Center for Atmospheric Research atmospheric nonhydrostatic mesoscale model (MM5) to characterize the mesoscale structures of atmospheric synoptic forcing, especially for the wintertime Siberian cold-air outbreaks in the offings of Vladivostok and in the vicinity of the subpolar in JES. Our general approach is to use multi-nested grids model to cover a large area in the outer domain and still resolve the fine mesoscale features in the inner domains. We use a triple-nest with 45, 15, and 5 km grid spacing for the outer and two inner domains, respectively. The outer domain covers a large portion of the Asian Continent and the northwest Pacific Ocean. The 15-km grid inner domain covers the JES region. The 5-km grid inner-most domain is centered near Vladivostok, Russia where the strong, persistent valley winds were observed. The ECMWF global analysis fields and the NCEP global SST analysis are used to initialize MM5 and provide continuous lateral boundary conditions. The outer domain is run in a four-dimensional data assimilation (FDDA) mode to provide the best possible boundary conditions for the inner domains. The two inner nested domains are run in a forecast mode with no FDDA. To explore the impact of the high-resolution model simulated surface forcing on surface waves, we use the NOAA WAVEWATCH III model with the MM5 surface wind as the forcing field. The wave model grid spacing is 1/12 degree (~7 km). In collaboration with Dr. Mooers' ocean modeling group at RSMAS/University of Miami, we use the MM5 surface wind and fluxes to test the impact of the high spatial and temporal resolution forcing on the ocean circulation using the Princeton Ocean Model (POM).

WORK COMPLETED

We have completed a month long MM5 simulation which contains three major extratropical cyclones associated with winter-time cold-air outbreaks and four weak synoptic disturbances over the Japan/East Sea region during January 1997. The model simulation has been validated with both the satellite and in situ observations including the Japanese Geosynchronous Meteorological Satellite (GMS-5) infrared cloud top temperature and water vapor images, the NASA Scatterometer (NSCAT) surface winds, and the surface measurements from the stations near the coastal regions and the JMA buoy at (39^{o}N, 138^{o}E). We have also conducted number of sensitivity simulations using various atmospheric boundary layer schemes to examine the validity of the currently physical parameterizations in the atmospheric models.

We conducted a month-long ocean surface wave model simulation using the NOAA WAVEWATCH III with the grid spacing of 1/12 degree (~7 km). The model results have been validated with observations taken at the JMA moored buoy in JES.

In addition to model simulations and data analyses, we have developed a real-time meteorological data archive and display system online at RSMAS/UM for the JES region (http://orca.rsmas.miami.edu/jes). This web site has been used by many ONR JES PIs. We have used this interactive display system to provide field program summaries on meteorological conditions for both Summer 1999 and Winter 2000 JES field programs. The PI and two research associates at RSMAS/UM also provided real-time weather forecasts for both the R/V *Revelle* and the CIRPAS Twin Otter missions during January-February 2000.

RESULTS

The main results from the previous two years have been summarized in two manuscripts (Chen, 2000, JMSJ; Chen et al., 2000, JGR). The one-month long MM5 simulation captured the observed structure and the evolution of the three cold-air outbreak events over the JES during January 1997. The storm tracks matched closely with the satellite observed center locations of the storms from the IR and water vapor images. The model simulated surface wind gusts were up to 25 m s^{-1}, which is very close to the observed 28 m s^{-1} at the JMA buoy during the first storm on 1 January 1997. The air-sea temperature difference reached 10-15^{o}C behind the surface cold front similar to the observed value. These extreme conditions induce strong surface heat and momentum fluxes. The surface wind and rainfall patterns were greatly modulated by the complex coastal terrain surrounding the JES. The enhanced valley winds near Vladivostok were very persistent associated with both storms. To evaluate the model simulated surface wind, we first compared the MM5 surface wind with the in situ measurement from the JMA buoy, which shows the MM5 wind field tracks observation very well. We then compared the results with the ECMWF global analysis field and the NSCAT winds. Chen et al. (2000) shows clearly that the ECMWF surface winds cannot capture some important features associated with the complex coastal topography such as the strong level jet near Vladivostok. The NSCAT swath data matches the buoy measurement very well. However, the NSCAT gridded products often miss-represent the flow patterns associated with the storm evolution due to the lack of data coverage in time and space.

A series of MM5 runs have been conduced using different physical parameterizations to examine the sensitivity to various physical representations in the model under the extreme conditions, especially the atmospheric boundary layer (ABL) structure and air-sea fluxes. Three ABL parameterizations in MM5 produce rather different ABL structures. So far the results are inconclusive because of the lack of observations in JES to evaluate the model simulations. The most recent data obtained by the CIRPAS Twin Otter aircraft supported by ONR will shed some new lights on the ABL structure in JES during the winter storms.

It has been a known problem that the current global wave models under-predict significant wave high (SWH) forced by the low-resolution global model surface winds. Using MM5 produced surface wind field, WAVEWATCH III reproduced the observed SWH quite realistically. The simulated SWH tracks the observed SWH from the JAM moored buoy very well for the entire month. SWH reaches 8 m or higher during the three major storms. The SWH is about 4-5 m for four moderate synoptic disturbances in the region. The SWH increases in the down-wind direction toward the coast. We are currently in the process of conducting sensitivity simulations to examine the importance of the spatial and temporal resolution of the surface wind field on surface wave prediction.

The MM5 simulated surface wind and fluxes are used to investigate the impact of the relatively high-frequency synoptic winter storms on the ocean circulation in the Princeton Ocean Model (POM). A series POM simulations with various atmospheric forcing fields, including the ECMWF analysis, the NSCAT gridded data, and MM5 high-resolution simulations, indicate that the ocean model is very sensitive to the high-resolution synoptic-scale surface forcing. The results are summarized in Mooers et al. (2000).

IMPACT/APPLICATIONS

This project has provided the first high spatial and temporal resolution surface forcing (heat and momentum fluxes) associated with the wintertime Siberian cold-air outbreaks in JES. The one-month long MM5 simulated surface forcing fields have been used to drive the ocean circulation and surface wave models. Recent ocean circulation and wave model simulations using this MM5 surface forcing have show a great sensitivity in ocean response to the high-resolution atmospheric forcing which is very different from that climatological mean forcing and the ECMWF global. Future coupled atmosphere-ocean modeling work can provide some insights of the air-sea interaction and its potential impact on the deep ocean ventilation processes in JES.

TRANSITIONS

The full three-dimensional, high-resolution atmospheric forcing fields (including all surface fluxes) has been made available to all ONR JES PIs for their data analysis in JES and to the ocean modeling groups at NRL and UM as well other ONR supported modeling efforts. We are also comparing the MM5 simulation with the COAMPS simulation in JES from Dr. Q. Wang of NPS. The results will be communicated with Dr. J. Doyle at NRL/Monterey.

RELATED PROJECTS

Related projects include the ONR Arabian Marginal Sea and Gulf, the NASA Scatterometer and QuikSCAT.

PUBLICATIONS (2000)

Chen, S. S., 2000: A high-resolution model simulation of winter storms in the Japan/East Sea. *J. Meteor. Soc. Japan*, submitted.

Chen, S. S., R. C. Foster, J. Tenerelli, and C. N. K., Mooers, 2000: Comparison of surface winds from NSCAT swath and gridded data and an atmospheric mesoscale model, *J. Geophys. Res.*, submitted.

Mooers, C. N. K., H. Kang, S. S. Chen, 2000: Several aspects of the simulated response of the Japan/East Sea to synoptic atmospheric forcing due to Siberian cold air outbreaks, *Proceedings of the 5th International Marine Science Symposium on the Physical, Biological, Chemical, and Geological Processes in the Pacific Ocean and Asian Marginal Seas*, in press.